ORION Downconverter and Power Supply

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The receiver subsystem supplies the front end assembly (downconverter) and power supply for the ORION Mobile Station. These assemblies are designed to withstand severe environmental conditions. This article discusses the mechanical, electronic, environmental and maintenance design considerations encountered during the design phase of this project. The two channel S/X downconverter has a 400-MHz bandwidth channel. Phase stability of 2 and 7 deg at S- and X-bands, respectively, has been achieved with a temperature stabilized first local oscillator.

I. Introduction

The ORION Receiver Subsystem is a part of the Crustal Dynamics Project's ORION Mobile Station. The ORION Mobile Station is the mobile portion of the ORION network which uses VLBI techniques for determining earth crustal deformations. Radio energy from extragalactic star sources is simultaneously recorded at two sites to determine through interferometry the vector length and direction between the sites.

This article discusses the design of the Receiver Subsystem's frequency downconverter. (The downconverter is a low phase drift device which converts incoming frequencies at S- and X-bands to intermediate frequencies.) The downconverter is capable of operating in desert as well as arctic environments. During nonoperational transport, the receiver must survive air shipment and road-induced vibrations. An ORION downconverter is currently being fabricated that will meet these requirements (see Fig. 1).

II. General Description

The receiver subsystem consists of two separate assemblies: (1) the downconverter which contains the electronics necessary for converting the incoming S- and X-bands frequencies to the intermediate frequencies, and (2) the power supply, which provides all of the ac and dc requirements of the downconverter. The power supply also supplies dc voltages to the Phase Calibration Subsystem.

The downconverter and power supply are designed for outdoor mounting with protection from the elements; the equipment package is bulkier than the usual electronic assemblies used in a protected environment. Both assemblies use wall-box types of enclosures. They are part of the antenna transporter mobile unit. During operation they are mounted above the elevation bearings of the microwave dish antenna. However, while being transported between measuring sites, the equipment is stowed on the transporter bed.

Phase stability is one of the important requirements of the downconverter. To achieve good stability, the first local oscillators operate within a temperature-controlled environment. Controlled monitoring of the vital functions is provided to the ORION system computer. The maintenance concept is simplified through the use of appropriate LED failure indicators within the enclosures. Components subject to field replacement are readily accessible and have been designed for ease of replacement.

To overcome the effects of desert temperatures and solar loading, thermoelectric (T/E) coolers are used in the downconverter.

III. Design Discussion

A. Layout and Packaging

The packagings for the downconverter and power supply are similar in that they both utilize Hoffman wallbox enclosures and rear-mounted heat dissipating fins (see Figs. 2 and 3). Beyond these similarities, the layouts and packaging methods are quite different.

In the power supply the individual power supply modules are mounted directly to the flat side of the heat dissipating fins which form the floor of the enclosure. This provides a low center of gravity as well as a good thermal conductive path from the power modules into the fins.

The downconverter layout is based upon the following considerations: serviceability, component density, temperature-sensitive components and rf grounds. The resultant layout consists of three oven assemblies in one sector of the enclosure, all mounted upon a common subplate. The multipliers within the ovens are temperature-stabilized by T/E coolers. The balance of the enclosure floor area has three vertically mounted component plate assemblies which contain the rf components for accomplishing the downconversion. The amplifiers and passive components, which are not as susceptible to temperature as the multipliers, are mounted on these plate assemblies. The vertically mounted plates provide adequate thermal conduction and convection cooling for the heat from the mounted components.

B. Electronic Considerations

The electronic specifications of the downconverter are listed in Table 1. One of the design objectives was the utilization whenever possible of easily obtainable, commercial off-the-shelf electronic components, thereby minimizing in-house development and in-house manufacturing costs. As a result, the downconverter contains only three JPL-developed low-cost components. The usual specially manufactured semirigid hardlines were replaced with commercial Gortex flexible cable assemblies which are superior in phase stability and attenuation characteristics to their conventional semirigid counterparts. Despite their higher initial cost, the new cables eliminate costly documentation and fabrication and are much easier to handle in the field.

Phase instability is primarily introduced into the downconverter by the first local oscillator multipliers, the times twenty (×20) and the times eighty-one (×81) assemblies. The other components, such as amplifiers, mixers and cables contribute little to the overall instability. In order to achieve required overall stability, component ovens in conjunction with T/E coolers are used to control the temperature of the ×20 and ×81 multipliers. Temperature design is discussed in more detail in the Environmental section of this report.

A wide bandwidth (400 MHz) system when used with conventional coaxial cable suffers from gradual amplitude decrease at the high frequency end of the band due to the attenuation characteristics of the cable. In the Orion project, this cable is about 200 feet long. A compensating network of the same but opposite slope as the cable is required to maintain a constant amplitude IF input signal at the data acquisition assembly at the far end of the cable. A cable equalizer was designed for operation between 100 and 500 MHz, using a single section of a high pass network with an attenuation slope of −5.5 dB per 400 MHz. The circuit maintains a constant resistance of 50 ohms at both ports across the band.

Phase calibration tones are injected into the receiving channels in the microwave subsystem. These tones are sent through together with the noise signals and appear within the downconverter channels as a picket fence spectrum. The tones periodically produce a peak power that is much greater than the noise power of the signal. For this reason it is necessary to maintain the noise level well below the 1-dB saturation point of the downconverter. In order to minimize the intermodulation products caused by the amplitude distortion near saturation, it is also desirable to maintain the noise power at a safe margin below the 1-dB saturation point. Because of their combined effects, the noise level in the S-band channel has been designed to remain at 27 dB below the 1-dB point, and 32 dB below in the X-band channel.

C. Monitor and Control

The downconverter and the power supply provide analog data indicating the operating parameters, such as output levels, phase lock and internal temperatures. This data is hardwired to the Monitor and Control subsystem. The following list identifies all the monitored data:

Monitored data

Downconverter

IF output levels, S- and X-bands

X20, X81 and X5 multiplier output levels

Internal temperatures of enclosure and ovens

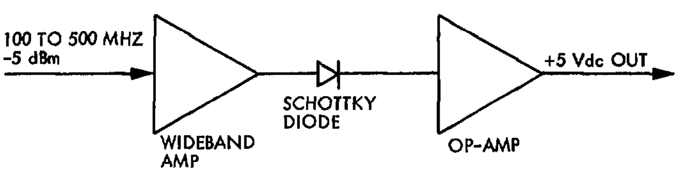
Multiplier phase lock

Power supply

Output voltages of individual power modules

Internal box temperature

Commercial power level packaged detectors usually require about a +7 dBm input level in order to obtain a +0.4 Vdc output level. For continuous IF level monitoring, a more sensitive detector was required. A Schottky zero bias diode was used in a new design to provide the necessary level to the Monitor and Control Subsystem. In the design, the diode is preceded by a wideband IF amplifier for additional sensitivity. The diode output was connected to a dc op-amp for level amplification. Sensitivity is better than -30 dBm, although -5 dBm is all that is required.



Internal temperatures are monitored within the downconverter and power supply by mercury thermostats which are preset by the manufacturer. At the predetermined temperature the thermostat contacts either open or close. The contacts are connected to TTL level pull-up resistors. These levels are sent through the Monitor and Control Subsystem to the system computer as warning indicators. In the power supply one of the sensors automatically shuts down the entire power supply when the internal temperature reaches a danger level. A power relay is used for this purpose.

D. Environmental Considerations

Equipment is designed to operate under the following environmental conditions:

Conditions	Operational specifications
Temperature	-29 to 45°C (-20 to 113°F)
Wind speed	48 km/hr (20 mph)
Relative humidity, maximum	100% at 46°C (115°F)

The downconverter and power supply require protection from the environment. The Hoffman aluminum enclosures provide adequate protection from blowing sand and rain. Unlike the downconverter, the power supply can withstand the temperature extremes without excessive degradation of its output parameters. Therefore, the power supply design is, relatively speaking, more straightforward than the downconverter.

The basic mode of heat removal on the power supply is by conduction and forced air convection. The floor of the enclosure was replaced with a finned heat dissipator. To prevent the external fins from absorbing solar load, a shroud was built over the fins to act as a sun shield. The shroud also helps to distribute the air from a blower mounted at one end of the shroud. The heat dissipator is mounted to the enclosure with screws instead of weld in order to prevent the welding heat from distorting the machined inner mounting surface of the aluminum dissipator. The individual power modules are mounted on the inner or smooth surface of the dissipator. The heat is conducted from the base of the power modules into the heat dissipator. Forced air convection removes this heat from the fins into the atmosphere.

The downconverter design utilizes, in addition to the cooling methods of the power supply, thermoelectric (T/E) coolers and a special subplate for the purpose of mounting the multiplier ovens. The subplate, which is smaller than the main baseplate, requires fewer T/E coolers than a bulky baseplate. The three frequency multipliers (two for the downconverter and one for the Phase Calibration Subsystem) require precision temperature control. Each is contained within a component oven slightly larger than the multiplier. Individual ovens are preferred from a maintenance viewpoint. The oven cavity temperature is maintained to within ±0.1°C of the 48°C set temperature by a proportional controller energized by dc. All three ovens are mounted on the common subplate, which is thermally isolated from the baseplate or any part of the enclosure. Six T/E coolers are sandwiched between the subplate and the external finned heat dissipator. With the T/E coolers connected in the cooling mode, the heat from the subplate is transmitted to the fins. Like the power supply and its shroud, a blower on the downconverter blows external air across the fins to dissipate the heat to the atmosphere. The heat dissipating efficiency is preserved by mounting the downconverter on the movable antenna structure in such a way that the fins are never below the main enclosure. This prevents the warm air coming off the fins from reheating the enclosure.

Figure 4 shows the main elements of the oven design. The oven is made from a standard component oven which is rated for a cavity load of 2.5 watts.

In order to keep the oven volume as small as possible, the smallest available oven was used. The same oven was selected for the S- and X-band and Phase Calibration Subsystem multipliers. The design approach consisted of sufficiently modifying the standard ovens so that their cavities would be capable of dissipating from 4.5 to 6.5 watts of load. As discussed in the previous paragraph, T/E coolers, heat dissipating metal fins and forced air cooling methods were used. The subplate on which the ovens are mounted is maintained at 40 ±3°C. The thermal gradient from the subplate to the multiplier is accomplished with a metal shim of low thermal conductivity such as stainless steel.

Heat removal from the downconverter is a concern only at the higher ambient temperatures, e.g., 15°C (59°F) to 45°C (113°F). At temperatures below 15°C heat must be added to maintain the oven temperatures. Two methods of heat addition are employed: (1) polarity reversal of the T/E coolers, and (2) ac-powered path heaters. Although the T/E coolers function well as heaters with essentially the same efficiency as in the cooling mode, their heat adding capability is insufficient as the ambient temperature approaches the colder end of the operating range. The patch heaters turn on when the subplate can no longer be maintained within the 40 ±3°C range. The patch heaters are equipped with a proportional controller. All other controls are accomplished with preset mercury thermostats and relays.

Condensation is expected to become a problem when the temperature of the trapped humid air within the downconverter is lowered to its dew point. The resulting water droplets can cause rapid oxidation, resulting in poor contacts, especially at the rf connectors. For protection against condensation, a dessicant of silica gel is mounted in a pocket on the inside of the downconverter cover. The silica gel crystals are individually contained in cloth bags.

E. Maintenance

Maintenance philosophy was tailored for mobile requirements. Equipment servicing while on the road consists of no more than simple replacement of modules or assemblies. Although no time limits were specified for servicing, replacement time of 30 minutes was the design goal. Any maintenance requiring more than 30 minutes would be performed at the ORION depot. There is no soldering during field servicing. Connectors and screw terminals were extensively designed into the equipment to facilitate servicing. Commercial components with solder terminals were redesigned to accept screw terminals and connectors. LED-type indicators are employed to quickly pinpoint the problem areas. Desiccant was purchased in cloth bags to simplify replacement. Terminal board junction points were eliminated in favor of internal wire splices to reduce the package size. Troubleshooting time was decreased by wiring all critical internal test points to a 61-pin test connector located on the assembly bulkhead. At this connector measurements can easily be made with a simple external test fixture.

The power supply and downconverter are mounted during operation on the antenna structure. The enclosure covers and sun shield are easily removable for servicing these assemblies, which may at times be at difficult angles. On both the power supply and downconverter, with the removal of the covers, the internal components are readily accessible for servicing. Each oven is designed in a single assembly, called an oven cover, which is removed from the subplate by thumb-release latches. The desiccants, which may require replacement on a once-a-year basis, are equipped with a visual color type of indicator to monitor the moisture content within the downconverter enclosure. The frequency of desiccant replacement depends on how often the covers are removed and the humidity of the operating environment. The environment within the downconverter is a closed system with no outlets to the atmosphere.

IV. Testing and Implementation

The receiver tests will commence in May 1982. The multitude and length of some of the anticipated tests are expected to make the testing phase a very important part of the overall program. Because of the very short time allowed before the receiver is integrated with the rest of the ORION system, some of the tests will be postponed until later. Tests will be conducted across the ambient temperature of -29 to 45°C and across the frequency band of each IF. Each channel of the downconverter will be tested independently. Thermal stability will be checked at the multipliers and the subplate on which they are mounted. Phase stability, phase linearity and phase jitter will be checked as a function of temperature and/or frequency.

The power supply will be tested for input step voltage variations, output ripple, and output stability with load variations.

Implementation of the receiver subsystem is expected to commence in July 1982. Manufacturing documentation will be updated at this time to reflect the final tested model.

Table 1. Downconverter electronic specifications

Input characteristics	Performance
Frequency range	S-band: 2220 to 2320 MHz X-band: 8200 to 8600 MHz
Signal level	
S-Band	-65.2 dBm ±0.4 dB
X-band	-66.8 dBm ±1.2 dB
Reference signal	100 MHz, +5 dBm
Noise figure	S-band: 280 K (2.9 dB) X-band: 400 k (3.8 dB)
AC voltage	117 Vac, 60 Hz, single phase
AC power	800 W, max.
Output characteristics	**Performance**
S-band IF	300 ±50 MHz
X-band IF	300 ±200 MHz
Monitor and control interface	RS-232C
Phase stability	S-band: < 2° drift, temp stabilized X-band: < 7° drift, temp stabilized
IF amplitude stability	S-band: ±1.0 dB from 250 to 350 MHz X-band: ±1.5 dB from 100 to 500 MHz

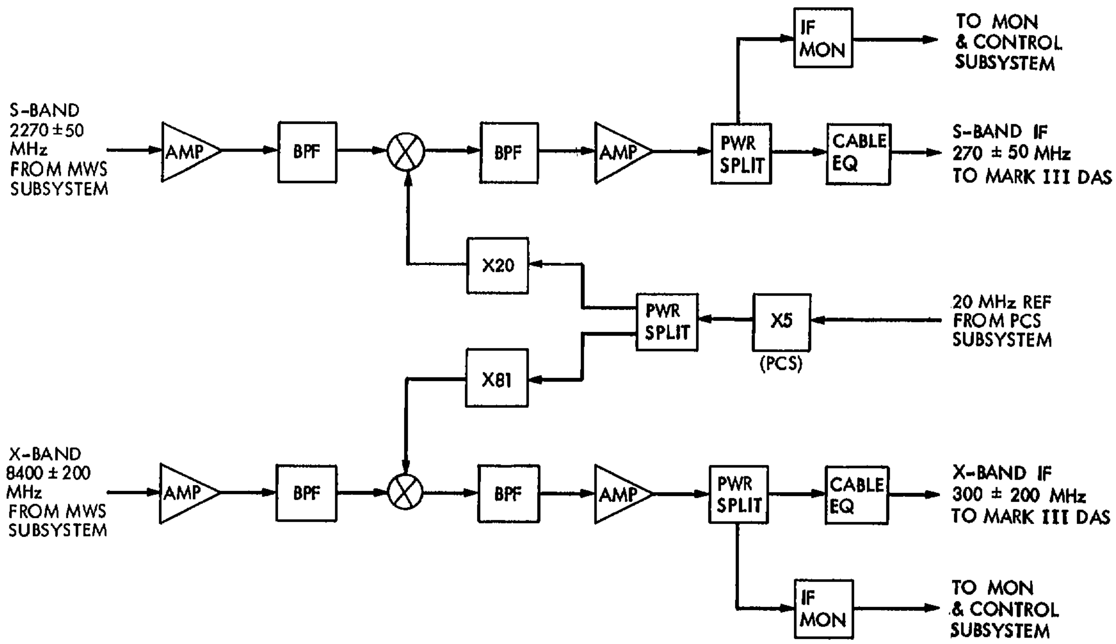


Fig. 1. Downconverter block diagram (simplified)

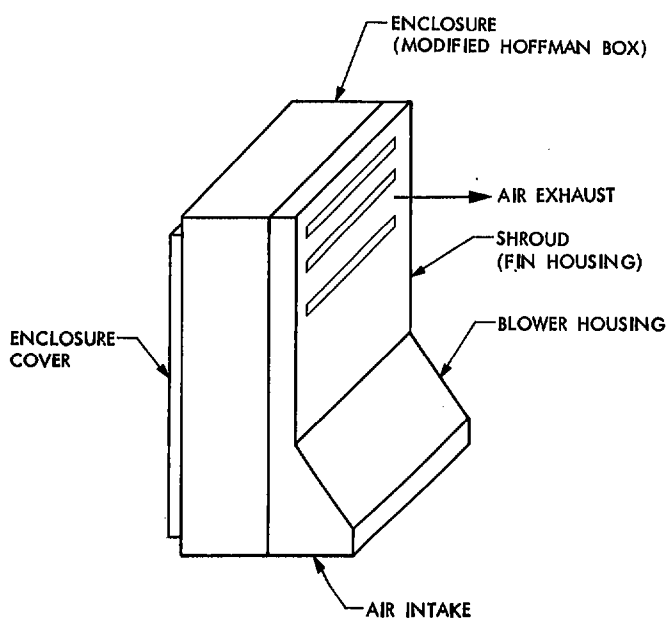


Fig. 2. Power supply enclosure

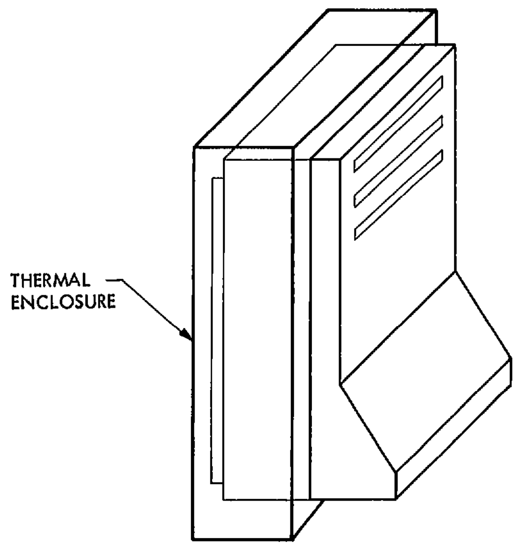


Fig. 3. Downconverter enclosure (power supply enclosure modified by adding thermal enclosure)

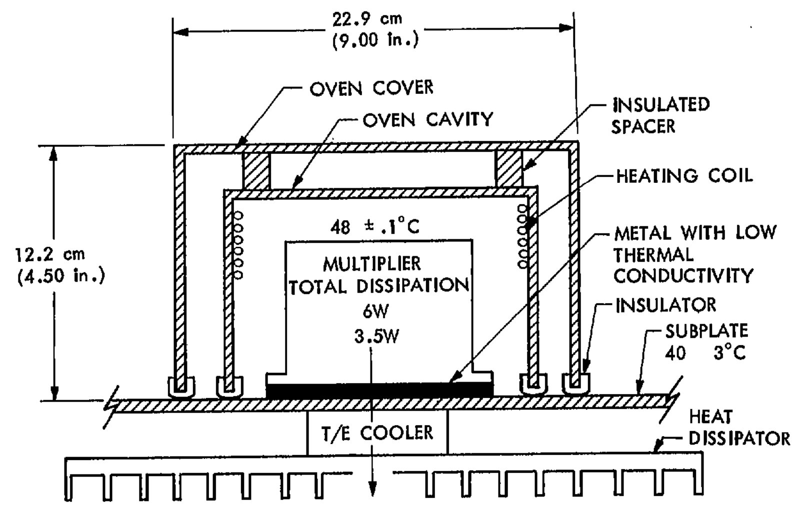


Fig. 4. Multiplier oven